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OPERATION OF THE TONTO FOREST SEISMOLOGI-  
CAL OBSERVATORY

Teledyne Geotech

Prepared for:

Advanced Research Projects Agency

20 January 1973

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TECHNICAL REPORT NO. 73-3

OPERATION OF THE  
TONTO FOREST SEISMOLOGICAL OBSERVATORY  
Quarterly Report No. 2, Project VT/3704  
Contract F33657-72-C-0800  
1 October through 31 December 1972

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13. ABSTRACT <i>This is a report of the work accomplished on Project VT/3704 from 1 October through 31 December 1972. It describes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona, research and test functions carried out at the TFSO, and research and development tasks performed by the Garland, Texas, staff using TFSO data.</i>			

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## OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 2, Project VT/3704

Contract F33657-72-C-0800

1 October through 31 December 1972

### 1. INTRODUCTION

#### 1.1 AUTHORITY

The work described in this report was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract F33657-72-C-0800. The effective date of the contract is 1 July 1972; the Statement of Work for Project VT/3704 is included in the appendix of this report.

#### 1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) was constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and seismometric recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965, by the Earth Sciences Division of Teledyne Industries under Contract AF 33(657)-7747. On 1 May 1965, Geotech assumed the responsibility of operating TFSO. The location of TFSO is shown in figure 1.

### 2. OPERATION OF TFSO

#### 2.1 GENERAL

Data are recorded continuously at the TFSO for 24 hours each day of the week. The instrumentation that accomplishes this, and other instrumentation that is used for special tests, have been operated and maintained during this report period by a staff of four technical people. Administrative work is handled by one half-time person. All work is being accomplished during a "normal shift" from 8:00 a.m. to 5:00 p.m., and a "late shift" from 9:30 a.m. to 6:00 p.m. The normal work shift is worked each Monday through Friday except holidays and is considered the regular work day by all personnel. The late shift is worked every day including Saturdays, Sundays, and holidays, and is staffed by one man on a rotational basis.

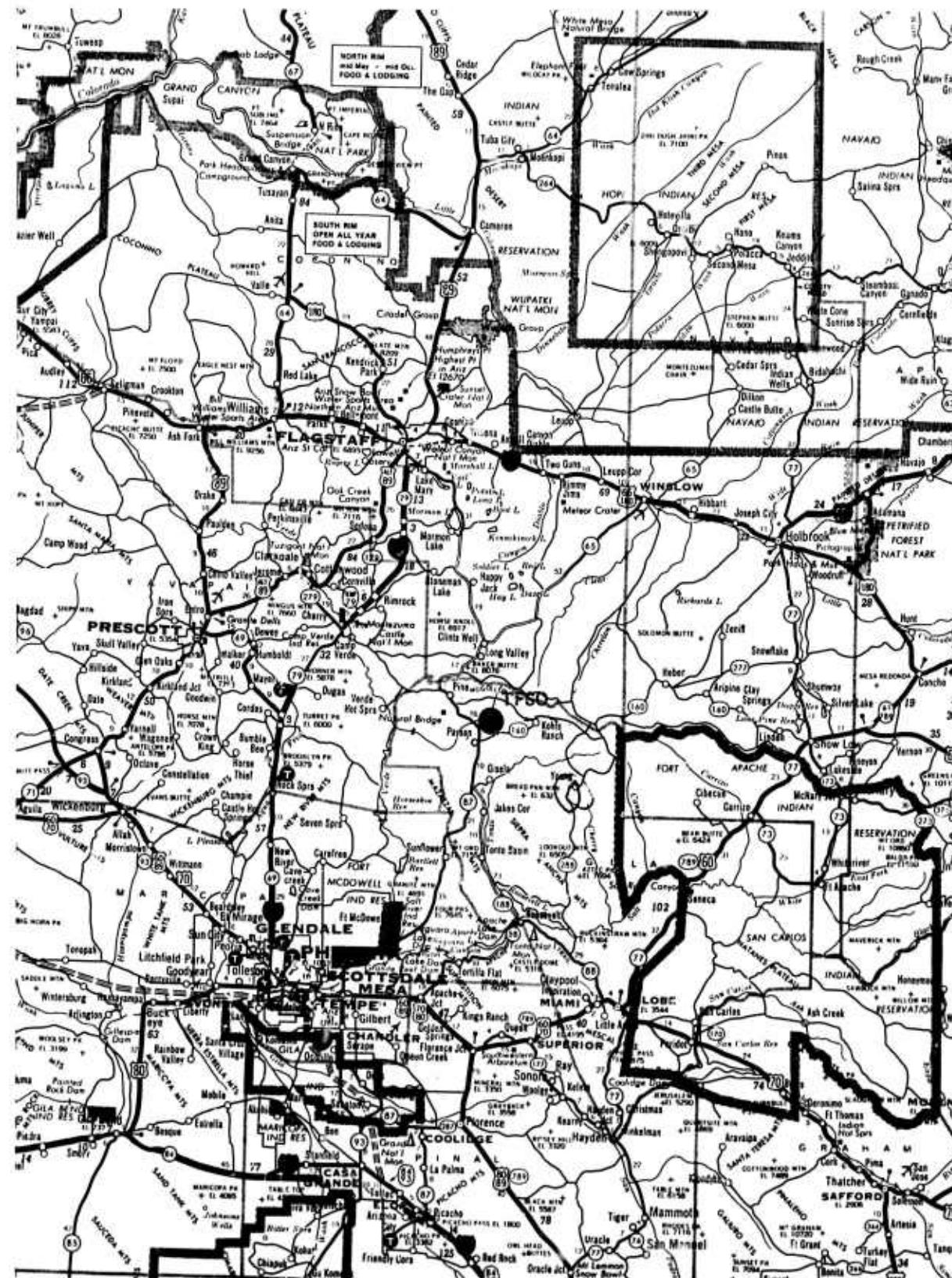


Figure 1. Location of the Tonto Forest Seismological Observatory

G 4970

## 2.2 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are made routinely and parameters are checked and reset to maintain the specified tolerances.

Normalized response characteristics of TFSO standard seismographs are shown in figure 2.

## 2.3 DATA CHANNEL ASSIGNMENT

Each data format recorded at TFSO is assigned a Data Group number. When a data format is changed, a new Data Group number is assigned. Data Format Change Notices reporting changes in channel assignments were submitted to the Project Officer and to frequent users of the TFSO data during this report period.

## 2.4 COMPLETION AND SHIPMENT OF DATA

Four analog FM magnetic-tape units were used to record data for the VELA Seismological Center (NYV). Tapes from these units were shipped weekly. All tapes recorded on 1 day were shipped to our Garland, Texas, laboratory for quality control, then shipped to the SDL. All tapes recorded on the other 6 days were shipped directly to the SDL.

All ASDAS tapes, except two per week that were sent to Garland for quality control, were held at the observatory for a period of about 8 weeks and then were recycled, if not requested by a data user.

All Devilocorder (16-millimeter film) seismograms, except quality control copies, were routinely shipped to the SDL. One seismogram for each Devilocorder was sent each week to our Garland, Texas, laboratory for quality control, then forwarded to the SDL.

One DGRDAS tape was sent to Garland each week for quality control, then was forwarded to the SDL. All other tapes were shipped weekly to the SDL.

Copies of calibration and operational logs accompanied all data shipments.

## 2.5 QUALITY CONTROL

### 2.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality control checks of randomly-selected 16-millimeter film seismograms from Data Trunks 2, 4, and 8 and the associated logs were made in Garland. Items that were routinely checked by the quality control analyst include:

- a. Film boxes - neatness and completeness of box markings;
- b. Devilocorder logs - completeness, accuracy, and legibility of logs;

Table 1. Operating parameters and tolerances of standard seismographs at TFSO

System	Comp	Seismograph		Operating parameters and tolerances				Filter settings										
		Type	Model	Ts	$\lambda S$	Tg	$\lambda g$	Model	Bandpass at 3 dB cutoff (sec)									
SPa	Z	Johnson-Matheson	6480	1.25 $\pm 2\%$	0.54 $\pm 5\%$	---	---	2888-1	0.2 - 1.0									
SPb	Z	Johnson-Matheson	6480	1.25 $\pm 2\%$	0.54 $\pm 5\%$	0.33 $\pm 5\%$	0.65 $\pm 5\%$	6824-1	0.1 - 100									
SPb	H	Johnson-Matheson	7515	1.25 $\pm 2\%$	0.54 $\pm 5\%$	0.33 $\pm 5\%$	0.65 $\pm 5\%$	6824-1	0.1 - 100									
SP	Z	Benioff	1051	1.0 $\pm 2\%$	1.0 $\pm 5\%$	0.2 $\pm 5\%$	1.0 $\pm 5\%$	6824-1	0.1 - 100									
SP	H	Benioff	1101	1.0 $\pm 2\%$	1.0 $\pm 5\%$	0.2 $\pm 5\%$	1.0 $\pm 5\%$	6824-1	0.1 - 100									
SP	Z	UA Benioff	1051	1.0 $\pm 2\%$	1.0 $\pm 5\%$	0.75 $\pm 5\%$	1.0 $\pm 5\%$	---	---									
BB	Z	Press-Ewing	SV-282	12.5 $\pm 5\%$	0.45 $\pm 5\%$	0.64 $\pm 5\%$	9.0 $\pm 5\%$	6824-7	0.05-100									
LP	Z	Geotech	7505A	20.0 $\pm 5\%$	0.77	---	---	30024	80 - 300									
LP	H	Geotech	8700C	20.0 $\pm 5\%$	0.77	---	---	30024	80 - 300									
KEY																		
SP	Short period																	
IB	Intermediate band																	
LP	Long period																	
UA	Unamplified (i.e., earth powered)																	
BB	Broad band																	
Ts	Seismometer free period (sec)																	
Tg	Galvanometer free period (sec)																	
$\lambda S$	Seismometer damping constant																	
$\lambda g$	Galvanometer damping constant																	
a37-element hexagonal array																		
bLinear array and 3 comp																		

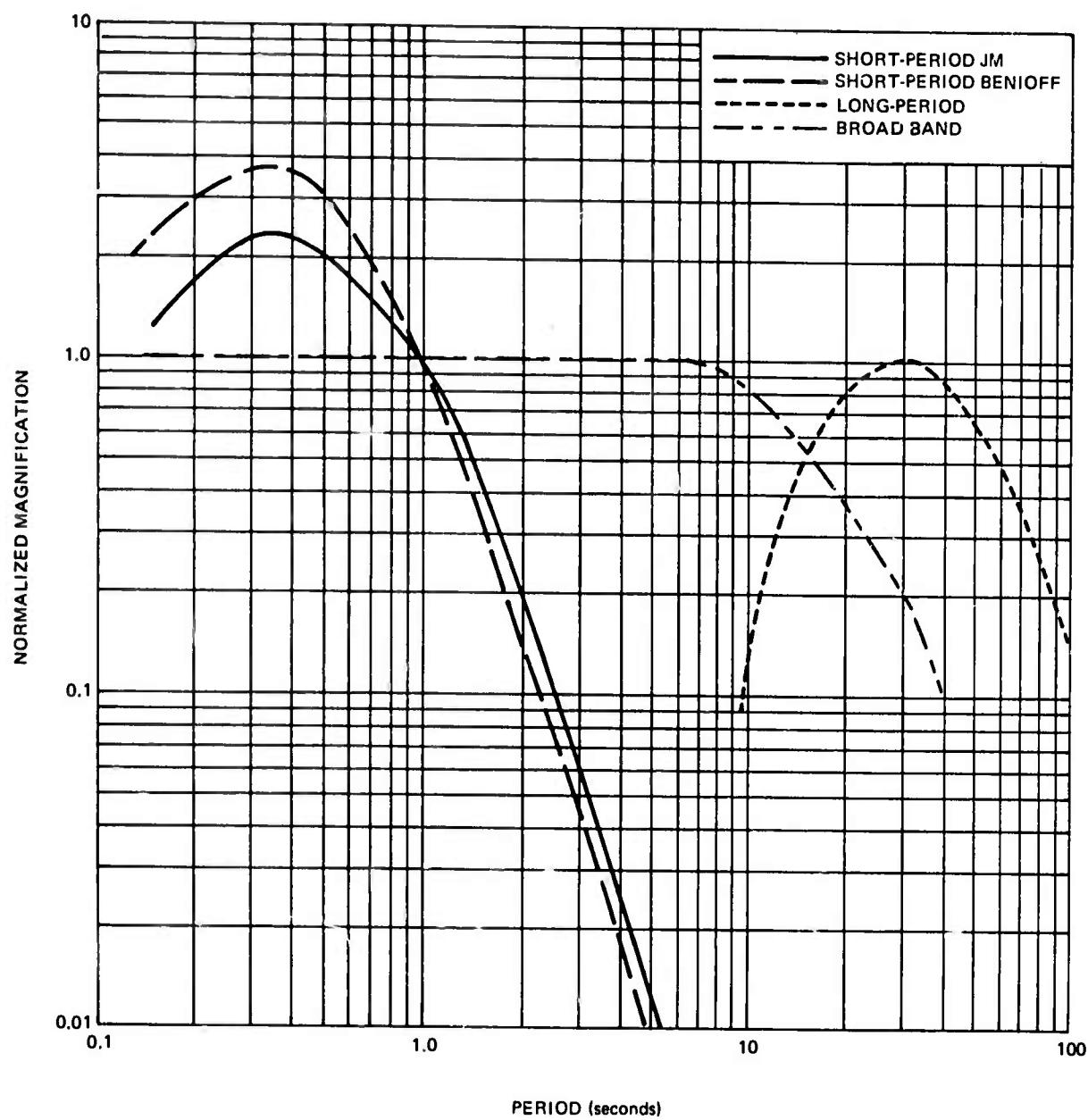


Figure 2. Normalized response characteristics of standard seismographs at TFSO

G 5048

c. Film -

- (1) Quality of the overall appearance of the record (for example, trace spacing and trace intensity);
- (2) Quality of film processing.

d. Results of these evaluations were sent to the observatory for their review and comment.

#### 2.5.2 Quality Control of Analog FM Magnetic-Tape Seismograms

Each week, quality control checks of three randomly-selected magnetic-tape seismograms are made in Garland and at TFSO to assure the recordings meet specified standards. The following items are checked:

- a. Tape and box labeling;
- b. Accuracy, completeness, and neatness of logs;
- c. Adequate documentation of logs by voice comments on tape where applicable;
- d. Seismograph polarity;
- e. Level of the microseismic background noise;
- f. Level of calibration signals;
- g. Relative phase shift between array seismographs;
- h. Level of system noise;
- i. Oscillator alignment;
- j. Quality of recorded WWV signal where applicable;
- k. Time-pulse carrier;
- l. Binary-coded digital time marks.

#### 2.5.3 Quality Control of ASDAS Magnetic-Tape Seismograms

Quality control checks of ASDAS tapes are made routinely. At present, one tape from each of the two transports is checked weekly for the following items:

- a. Neatness and accuracy of the associated logs;
- b. Polarity errors;
- c. Recording level of each channel;
- d. Fidelity of reproduction;

- e. Presence of header record and correct record length;
- f. Tape parity errors;
- g. Timing information.

#### 2.5.4 Quality Control of DGRDAS Magnetic-Tape Seismograms

Quality control checks of DGRDAS tapes are made routinely. At present, one tape is checked each week for all items listed under section 2.5.3, and, in addition, for the following items;

- a. Field transmission parity errors;
- b. Central digital system parity errors;
- c. Gain code errors.

#### 2.6 INSPECTIONS

On 4 October Messrs. R. L. Miller and J. E. Lindeman of the Arizona State Health Department inspected the TFSO waste water treatment facility and reported that maintenance should be performed to restore the system to a satisfactory operating condition. All required work was completed on 17 November. In response to an Arizona State Health Department request, Ranger Phil Smith, U. S. Forest Service, Payson District, inspected and approved the work done on the waste water treatment facility.

Mr. R. M. Santanore, Norzona Fire and Safety, inspected the TFSO fire extinguishers on 2 November. On the same day, Mr. Kenneth Ozbolt and Mr. J. H. Carmichall, Industrial Security, Phoenix, Arizona conducted a security inspection. All items inspected were found to be in good order.

#### 2.7 EMERGENCY POWER GENERATOR

The 100 kW diesel-powered generator was operated for a total of 5.5 hours. It was tested for 1.0 hour, and furnished full observatory power for 4.5 hours during commercial power failures.

#### 2.8 FACILITY MAINTENANCE

The TFSO facilities were maintained in accordance with sound industrial practices throughout the report period. This work included pest extermination, work area cleaning, and lubrication and cleaning of heating and air conditioning equipment.

The side of the furnace blew out on 14 November. It was repaired and returned to service the following day. However, since that time, the furnace has stopped operating frequently, and has required manual restarting. The furnace maintenance company has stated that the furnace is old and deteriorating, and

should be replaced. To date, no firm has responded to requests for an oil-fueled furnace to replace the one currently in service, although a Payson firm has quoted on a propane-fueled furnace.

#### 2.9 WEATHER

Lightning was observed in the TFSO area on 11 days during this quarter, and the temperature just outside the Central Recording Building varied from a minimum of 5°F to a maximum of 80°F. Rain or snow fell during 23 days.

#### 2.10 RELOCATION OF LP6

Telephone service to the new site has been delayed by the telephone company, which is awaiting the receipt of new carrier equipment to replace defective equipment shipped to them for use on this job.

#### 2.11 SPIRAL-4 CABLES

A total of 68 one-fourth-mile sections of spiral-4 cable were replaced, and 5 cables were spliced during the report period. Four cables were damaged by vandals, one was cut by a construction vehicle, one was chewed by an animal, two were damaged by lightning, and 60 failed because of insulation deterioration or for unknown reasons.

#### 2.12 IMPROVE TFSO INSTRUMENTATION

Engineering Change Proposal No. 3, Improve TFSO Instrumentation, was negotiated on 27 November. Detailed planning and procurement of long-delivery items have been started. The sewage system maintenance called for under this task was undertaken and completed.

### 3. INSTRUMENT EVALUATION

#### 3.1 DIGITAL GAIN RANGING DATA ACQUISITION SYSTEM

The digital gain-ranging data acquisition system (DGRDAS) was inoperative from 25 November through 28 November for maintenance on the tape tension arm. During the remainder of the report period, the DGRDAS was operated routinely except for cleaning and preventive maintenance. Seventy-five reels of tape recorded by this system were sent to the SDL and 15 reels were sent to Garland.

#### 3.2 ASTRODATA SEISMIC DATA ACQUISITION SYSTEM

Routine operation of the Astrodata seismic data acquisition system was interrupted only for the replacement of an active filter and a capstan bearing,

the adjustment of a channel sensitivity, and the realignment of a head assembly. Three reels of tape recorded by this system were sent to the SDL and 92 reels were sent to Garland.

### 3.3 MULTICHANNEL FILTER

The multichannel filter was not operated during this report period because too few short-period channels were operational to justify its operation.

### 3.4 GRAVITY FEED CHEMICAL SUPPLY SYSTEM

There were seven failures in the gravity feed chemical supply systems used to furnish fixer to LP Develocorders and one failure in the system that supplies fixer to a SP Develocorder. All systems were restored to service by cleaning or adjusting the flow control valves. There were no failures in the developer supply lines.

During December, three chemical supply systems were removed from service, completely cleaned, and returned to service. Later in the month, during a visit by the Project Officer and the Program Engineer, it was noted that dust collects in substantial quantities on the surface of the liquid in each chemical supply tank, and that it probably contributes strongly to the system clogging. Plans were formulated to modify the system so that the chemicals could be kept clean and could be furnished to each control valve at a greater pressure (head) than is now used.

### 3.5 SHORT-PERIOD 37-ELEMENT SEISMOGRAPH ARRAY

The operational status of the SP array during the report period is shown chronologically by channel in figure 3. Four channels were inoperative during the entire period, 10 other channels were inoperative during some portion of the time period, and 12 channels were noisy during some portion of the time period. The channel malfunctions were caused by failures of the following components:

<u>Component</u>	<u>Number of failures</u>
Amplifier	1
Spiral-4 cable	22
Unknown (channel still inoperative)	4

The amplifier became inoperative on a stormy day and is presumed to have been damaged by a lightning surge induced into the telemetry line. A transistor in the telemetry output circuit required replacement.

Spiral-4 cable failures continue to be the greatest cause of channel outages.

SOLID LINE INDICATES CHANNEL OUTAGE  
 DASH LINE INDICATES NOISY CHANNEL

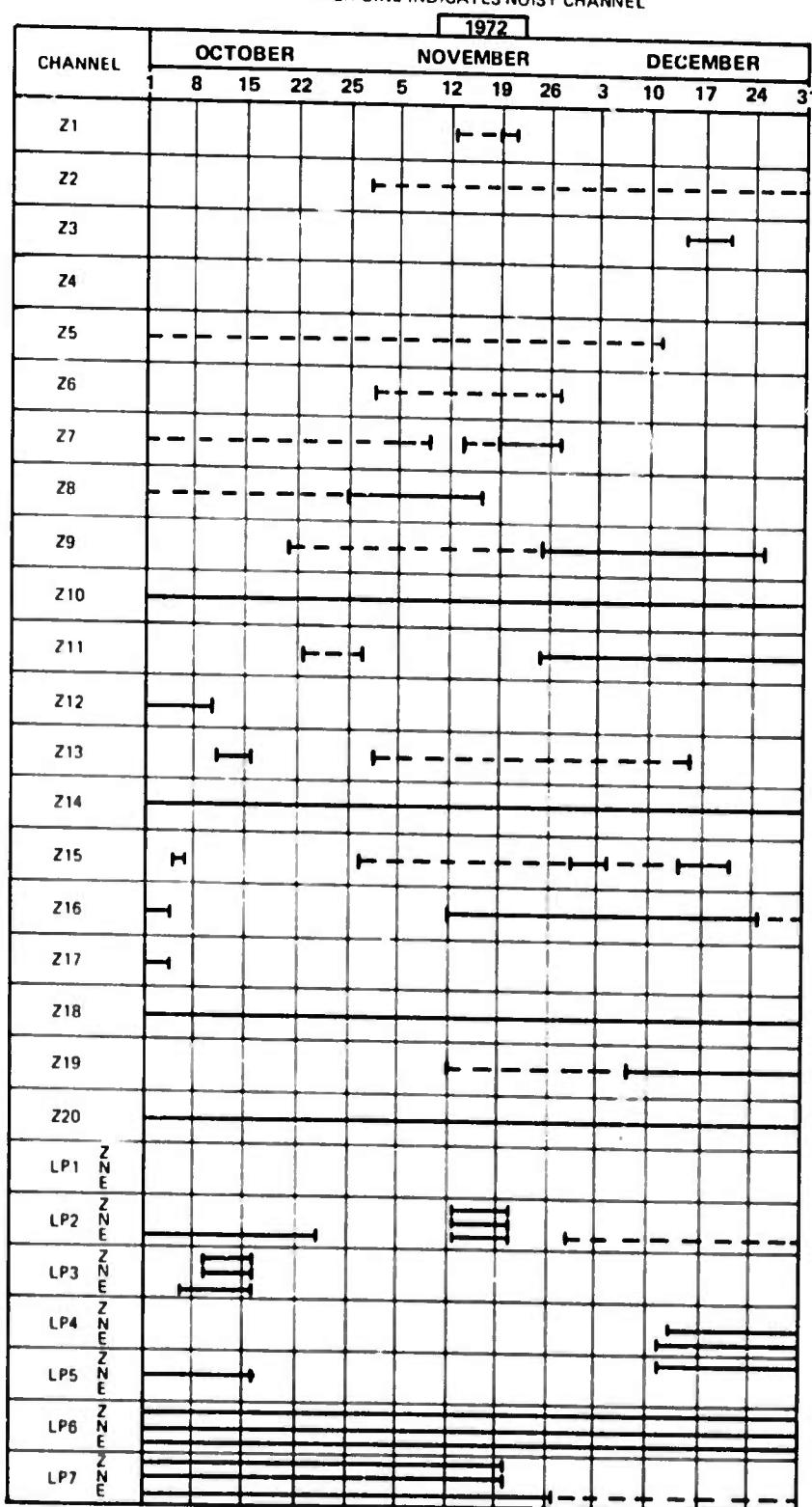


Figure 3. TFSO channel outage

### 3.6 LONG-PERIOD SEISMOGRAPH ARRAY

The operational status of the LP array during the report period is shown chronologically by channel in figure 3. All three LP6 channels were inoperative throughout the period because the relocation work has not been completed. Twelve of the other channels were inoperative or noisy during part of the period. The longest outages occurred in the LP7 channels, which have the greatest lengths of spiral-4 cable.

Channel outages were caused by the following component failures:

<u>Component</u>	<u>Number of failures</u>
Spiral-4 cable	7
Seismometer mass against stop	7
Wet vault	1
Radio equipment	1
Telephone circuit	1

Moisture introduced by heavy rains was responsible for most of the failures in the LP array channels. This wet the vault and the cables, causing electrical leakages, and changed the ground water content, tilting the vaults and causing seismometer masses to swing against their stops.

### 3.7 QUARTZ ACCELEROMETER

The work of testing and evaluating the Block and Moore quartz accelerometer will be described completely in a separate report, Geotech Technical Report No. 73-2, Evaluation of Block and Moore Quartz Fiber Accelerometers.

### 3.8 LAMONT-DOHERTY ENCLOSURE

Operational testing of the Lamont vault was continued during the report period. Data recorded early in October indicated that the Lamont tank instruments performed more quietly than did the control tank instruments, but maintenance work revealed that the control channel noise was caused by a defective solid-state amplifier and by moisture in the tank and the circuit cable connector. After the amplifier was replaced and the tank and cable connector were dried, there was a period of intermittent operation which ended when one section of spiral-4 cable was replaced. During the last 6 weeks of operation, the control channel has been quieter than the Lamont channel. Moisture in the cable connections is suspected to be causing the Lamont channel noise. When the rainy weather abates, and when work schedules permit, the connections will be dried and sealed.

### 3.9 PACKAGE BOREHOLE SEISMOMETER

Engineering Change Proposal No. 1, Package Geotech-Designed Borehole Seismometer, was negotiated on 27 October 1972, and work on this task was begun immediately.

The majority of the parts for the holelock, stabilizer, strain relief and the cable head assembly have been designed and built, and partial assemblies have been made. A developmental model of the pneumatic seismometer locking and leveling mechanism and a solenoid-actuated pump were built and tested to prove the soundness of the design approach. The locking and levelling mechanism performed satisfactorily, but the solenoid-actuated pump was under-powered. It has been replaced by a motor-driven, spring-actuated pump, a model of which has been built and tested.

The seismometer housing design is complete except for one dimension that depends on the size of the electronics printed circuit boards. Twenty-five percent of the parts for this unit have been fabricated.

The holelock installation tool design is complete and all parts are being fabricated. A partial model of the unit was built and tested to aid in the selection of the holelock setting motor. A 10-foot section of standard 7-inch well casing has been used for the tests.

The design of all electronic and electrical circuits is complete and all component parts have been ordered. Laboratory models of all designs have been bench tested.

## 4. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

### 4.1 TELEDYNE GEOTECH

Tests on experimental force-balance long-period seismometers were conducted from 1 through 13 October by Mr. T. D. Trosper, and from 17 through 31 October and 17 through 24 December by Mr. O. D. Starkey. Both men are from the Geotech laboratories in Garland, Texas.

### 4.2 VISITORS

Capt. J. H. Fergus, Project Officer, and Mr. M. G. Qudzin, Program Engineer, visited the TFSO from 7 through 9 December to review work progress and to discuss plans for accomplishment of contract tasks.

APPENDIX to TECHNICAL REPORT NO. 73-3

STATEMENT OF WORK

STATEMENT OF WORK TO BE DONE

(AFTAC Project Authorization No. VELA T/3704/B/ASD)

1. Objectives: The Tonto Forest Seismological Observatory (TFSO) is unique in its low level of background seismic noise and in its capability as a research center, being equipped with various film, paper, and analog and digital recorders, a shake table, a large walk-in vault for instrument evaluation, and assorted test and measurement equipment. The purpose of this project is to operate this observatory as a source of high-quality seismological data for use in Government-sponsored research projects, to use the TFSO as a field test site for evaluation of new seismological instrumentation and procedures, and to support other research projects as directed by the project officer. This project should require a technical manning level of approximately four man-years.

2. Tasks:

a. Operation.

(1) Continue operating the TFSO according to established procedures (Standard Operating Procedures for TFSO, 1 Nov 1970), providing recorded data to the Government. Special data requirements anticipated will include, but not be limited to, recording signals from special events at the Nevada Test Site and supplying beam-formed, or multichannel filtered data, for use in evaluation of the effectiveness of the ARPA long-period arrays: Montana Large Aperture Seismic Array, Alaskan Long Period Array, and Norwegian Seismic Array.

(2) Quality control the data acquisition systems and evaluate the seismic data recorded to determine optimum operating characteristics and perform research to improve operating parameters to provide the most effective observatory practicable. Major reconfigurations in equipment, those requiring more than 48 hours to remove, are subject to prior approval by the project officer.

(3) Provide use of observatory facilities and seismological data to requesting organizations and individuals as identified by the project officer.

(4) Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

b. Instrument Evaluation. Evaluate the performance characteristics of experimental equipment identified by the project officer. This work includes investigation of the operational capability of dry film recorders, evaluation of the use of a single seismometer for obtaining both long- and short-period data, and study of altered modes of operation of cable

## PART II - THE SCHEDULE SECTION F (Continued)

links and radio transmission of data. Additional investigations will be initiated as problems requiring investigation are identified. The total level of effort on this task will not exceed one man-year.

c. Upon identification and prior to the disposition of any equipment determined to be excess to the needs of the project, the contractor shall notify the project officer.